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## Bus stop and bus terminal capacity

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### Abstract

Stockholm is growing fast leading to an increased demand for public transport services and facilities. This has subsequently led to challenges to provide suitable bus terminals. The Municipalities are keen to provide good public transport but have difficulties providing the needed space. There is also a lack of knowledge in this problem area. A comprehensive study is therefore undertaken including literature review, field studies and modeling of the capacity of different types of bus stops and bus terminals.

In order to understand and evaluate the capacity of the bus terminals, the starting point is the capacity of loading areas for which there is presently no approved Swedish methodology. A model of capacity based on bus dwell time described by HCM2000 has therefore been used. This model does not consider the bus arrival distribution; therefore it has been applied with a correction factor to better reflect conditions in large cities. Results from performed trials show that this correction factor is reduced at higher dwell time.

The calculation of loading areas capacity is the basis for the calculation of bus stop capacity in bus terminals. However, terminal factors such as scheduling and design of the terminals must be taken into account. The procedure for estimating the maximum number of bus departures is also handled in the study. In the long term deeper analysis will be required, e.g. the need for safety zone behind the reversing buses and the demand for dedicated places for layover parking. Socio-economic analyzes of congestion and longer detours because of the increasingly smaller bus terminals should also be raised in these discussions.

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**Keywords:** capacity; loading area; bus stop; angle berth; bus terminal

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## 1. Introduction

Stockholm is growing and the demand for land in the central region as well as public transport facilities is increasing. As a result, it has become a big challenge to plan and build needed terminals. The municipalities demand good public transport, but this is hard to accomplish without the extra space required. Lack of capacity is also a growing problem in the terminals, causing security risks and quality efficiency in traffic. The Public Transport Administration has therefore recognized the need to make an inventory of Stockholm's bus terminals, to identify their capacities, and to review and define the capacity of the terminals.

## 2. Literature review

The capacity of bus stops with single and double loading areas is important for the accessibility and reliability of public transport. Lack of capacity of the loading area increases travel time for busses. In order to understand and evaluate the capacity of the bus terminals, the starting point is the loading area capacity for which there is presently no approved Swedish methodology. A model of capacity based on bus dwell time described by "Highway Capacity Manual 2000" (TRB, 2000) has therefore been used as a starting point. The model includes average dwell time and coefficient of variation, clearance time, effect of traffic signals in front of the bus stop, and the probability of bus queue formation behind the bus stop.

Both HCM2000 and "Geometric Design Guide for Transit Facilities on Highways and Streets, Chapter5 Off-Line Transit Facilities" (AASHTO, 2010) describe a model of capacity based on bus dwell time for three key components:

1. *Bus loading areas (berths)*: Curbside spaces where a single bus can stop to load and unload passengers.
2. *Bus stops*: Can include one or more loading areas depending on how many buses that use this bus stop
3. *Bus facilities*: Roadways used by buses, may contain multiple bus stops along their length.

In the HCM2000 model bus stop capacity is dependent on the individual capacities of the loading areas that form the bus stop, see figure 1. The number of buses that can be served depends on the **Dwell time**, which represents the average amount of time a bus is stopped at the curb to serve passenger movements, including the time required to open and close the doors. Another important factor is the **Clearance time**, which represent the average of minimum time required for one bus to accelerate out of and clear the loading area for the next bus including any time spent waiting for a gap in traffic. The combination of these two factors time determines the average time an individual bus occupies the loading area. The third factor is the **Failure rate** defined as the probability that one bus will arrive at a loading area while another bus already occupying it. The combination of dwell time variability and a design failure rate provides an additional margin of time in the capacity analysis to ensure that most buses will be able to immediately use the loading area upon arrival. (AASHTO, 2010).

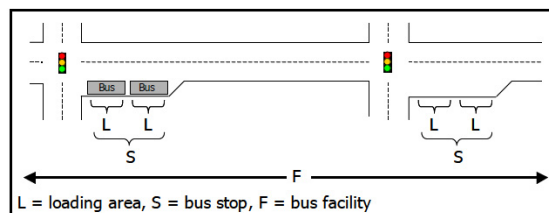


Fig. 1. Illustration of Bus loading areas, Stops, and Facilities (TRB, 2000).

A review of the Swedish guidelines and scientific studies shows that there is a lack of information on how the capacity calculation should be done. However, there are some recommendations and assessments of a bus stop capacity at on-street stops. The comments in this study have therefore proceeded from these assessments.

## 2.1. Loading area capacity

Recommendations and estimations of bus stop capacity with one loading area vary from one to another of the studied literature. Most studies limit the capacity for a loading area to 10–15 busses/hour. Variations in arrival time and dwell time were in some cases considered indirectly by specifying the difference in capacity depending on the number of routes served by the bus stop. Unlike other studies HCM2000 considers how the queue risk, coefficient of variation and clearance time affect the capacity of a bus stop.

### 2.1.1. Capacity of a bus stop in a terminal

The studied Swedish literature lacks models and analysis of their recommendations making it extremely difficult to draw conclusions or to apply their results for bus stops at terminals.

HCM2000 concept for terminal capacity is simply based on the sum of the capacity for all loading areas in the terminal. If the bus loading areas are long and accommodate more than one bus, the capacity per additional loading area drops, which means that the capacity for a bus stop with two loading areas is lower than two independent bus stops with one loading area.

## 2.2. Parameters included in the capacity calculation of bus stop capacity

### 2.2.1. Parameters included in the capacity calculation for a bus stop along the line

According to SKL “Better bus stops” (SKL, 2013) consideration should be taken to dwell times, clearance times and possible variations of arrival times in a detailed calculation of bus stop capacity.

The capacity of a bus stop depends on the time for entering as well as leaving the loading area which in turn is influenced by the bus stop design. Curb side bus stops give shorter times. Combined with more effective boarding and exit this can save 5–10 seconds per bus stop according to German studies referred by Wendle, (Wendle, 1997).

The bus stop capacity is also reduced if the bus stop is located next to a pedestrian crossing or a signal controlled intersection:

- Pedestrian and bicycle crossing reduce the street capacity by 10–30%. (SKF & SRA, 1999)
- Traffic calming measures adjacent to a bus stop reduce the capacity of single loading area with around 15% (SRA & SKF, 2004)
- According to the HCM2000 traffic signals have a major effect on the bus stop capacity. If the green time ratio ( $g/C$ ) is 0.5 the bus stop capacity is reduced by 25–37% (restated from figures), depending on the length of the dwell time. (TRB, 2000)

### 2.2.2. Factors affecting bus terminal capacity

One of the prerequisites for a good functioning terminal is good design. According to “Angle Terminals” (SL, 1987 & 1988) local traffic and environmental conditions should also be considered, e.g.:

- Design of the traffic system and bus traffic characteristics
- Available space size, location and design
- The possibilities to connect the terminal to the road network
- Pedestrian network design and location of target points for pedestrian traffic
- Vulnerability of the surroundings to disturbances

Related to this study workshops with bus operators have been organized in Stockholm. Some of the discussed ideas are listed below:

- Angle terminals increase driving time for buses and travel time for travelers, but may also increase traveler comfort.
- Reversing is usually perceived to be difficult and can lead to increased vehicle damage, especially problematic in times of stress.
- The berth must be wide enough and the island beside must be long enough to cover at least the area to middle door of the bus, otherwise boarding of prams will be difficult.

### 3. Model for bus stop capacity calculation

The calculation of bus stop capacity is based on the American model in HCM2000 due to lack of a Swedish model for this purpose.

#### 3.1. The highway capacity manual (HCM) model

In the highway capacity manual HCM2000, chapter 27 (TRB, 2000) the estimated capacity for a single bus stop is calculated as follows:

$$B_{bb} = \frac{3600 \left(\frac{g}{C}\right)}{t_c + \left(\frac{g}{C}\right)t_d + Z_a C_v t_d} \quad (1)$$

where:

- $B_{bb}$  maximum number of buses per berth per hour (buses/h)
- $g/C$  effective green time per signal cycle (1.0 for a stop not at a signalized intersection).
- $t_c$  clearance time between successive buses (s)
- $t_d$  average dwell time (s)
- $C_v$  coefficient of variation of dwell times = standard deviation/mean for  $t_d$  and
- $Z_a$  one tail normal variation corresponding to probability that queues will form behind bus stop, as in HCM2000 Exhibit 27-11 below

EXHIBIT 27-11. VALUES OF PERCENT FAILURE ASSOCIATED WITH $Z_a$	
Failure Rate (%)	$Z_a$
1.0	2.330
2.5	1.960
5.0	1.645
7.5	1.440
10.0	1.280
15.0	1.040
20.0	0.840
25.0	0.675
30.0	0.525
50.0	0.000

#### Discussion

- The equation has no term for the time it takes to enter the bus loading area, e.g. deceleration and turning movement
- The influence of traffic jams on routes without a reserved bus lane is only considered through the clearance time factor  $t_c$  regarding bus evacuation time for abandoning the loading area.
- The equation considers the presence of downstream traffic signals, but not pedestrian crossings or speed reduction measures.
- The risk of bus queue is calculated through  $Z_a$  assuming normal distribution probabilities of deviation from the mean in respect of bus dwell times,
- The effect of disturbed arrival frequency, for example due to the presence of bus platoons, is not considered in the equation.

This equation is deterministic and self-explanatory, but it does not consider the bus arrival distribution, which cause capacity overestimation since high arrival variance can be expected to lower bus stop capacity. Bus services in urban areas often result in bunching of buses in platoons behind the lead bus which gets longer dwell times. The equation should therefore be adjusted with a correction factor to better reflect public transport conditions in large Swedish cities.

#### 3.2. Application of the HCM model

In order to adapt the HCM model to Swedish urban conditions, field data was collected to enable estimation of a correction factor as discussed above.

### 3.2.1. Data collection

Field observations including data collection at a number of bus stops were performed in Stockholm as a basis for a more detailed analysis of the HCM2000 model. The surveys were carried out during rush hours at the following busy bus stop locations in Stockholm:

1. Two single loading area bus stops (Norrtull and Universities)
2. Two double loading area bus stops (Skanstull and Östra station)
3. Four angle berths at the bus terminal in Jakobsberg.

These sites were selected based on experience from the bus service operators and assessment of a reference group, which also was consulted to get an indication if the results of the adjusted equation are reasonable. All the selected sites were without down-stream traffic signals.

### 3.2.2. Capacity Calculation Methods

Three different methods were tested for estimation of bus stop capacity based on the collected field data:

1. Number of serviced buses at each loading area during active periods, i.e. when at least one loading area was occupied. The capacity per active hour was then calculated.
2. Number of serviced buses under saturated conditions defined as observed 25% probability that the arriving bus had to queue to enter a loading area (HCM2000 definition of practical capacity)
3. Number of serviced buses during a rush hour period. The rates of queuing buses were different in the studied sites and mostly were below the capacity.

### 3.2.3. Application of the HCM2000 model for bus stops with a single loading area

Application of HCM model was evaluated by comparing the results from the field measurement with calculations using the HCM2000 model for the same conditions, eg, the same rate of buses in queue. A correction factor (CF) was calculated as the ratio between relationship between measured and HCM's estimated capacity results as shown in Table 1 below.

Table 1. Capacity calculation for Single bus stop at Norrtull and Stockholm University.

Method	Proportion buses in queue %	$Z_a$	$t_d (sec)$	$C_v$	$t_c (sec)$	Buses/h from HCM2000	Buses/h field observation	Correction factor CF	Average CF
<i>Norrtull at morning</i>									
Active time periods	>50	0	15.97	0.31	5.63	167	120	0.72	
Saturated condition	25	0.68	16.64	0.31	5.36	142	53	0.37	
Rush hours	22	0.8	15.97	0.31	5.63	141	28	0.2	
<i>University after noon</i>									
Active time periods	>50	0	16.65	0.48	6.67	154	133	0.86	0.79
Saturated condition	25	0.68	15.27	0.58	7.01	127	53	0.41	0.39
Rush hours	14	1.05	16.65	0.48	6.67	113	31	0.27	0.24

- Method 1 assumes that the loading area would be occupied almost constantly, while the number of served buses was 79% compared to the HCM2000 model, which indicates that this model overestimated the capacity of the loading area at least for these two studied cases.
- Method 3 gave very low capacity (24%) compared to of the HCM2000 model since the loading areas were not occupied for extended periods.
- Method 2, based on that 25% of arriving buses had to queue to enter, corresponded to 39% of HCM2000 capacity. This level was considered as reasonable as a basis for practical design guidelines using a correction factor CF rounded to 0.4.

The deviation from the timetable and the number of buses arriving in platoons is reduced at higher bus dwell time  $t_d$ . The factor  $CF$  is therefore dependent on dwell time. Trials performed resulted in the following relationship:  
 $CF = 0.4 + t_d / 1000$ .

As discussed above the HCM 2000 considers the impacts of the signals but not adjacent pedestrian crossings and speed calming measures. All these effects may increase the clearance time  $t_c$ . Therefore, these factors were included in the model for calculation of  $t_c$ , and the factor  $g/C$  in the HCM2000 model was omitted leading to the following practical capacity model for design and operational analysis (applied model):

$$B_{bap} = \frac{(0.4 + \frac{t_d}{1000}) * 3600}{t_c + t_d + Z_a * C_v * t_d} \quad (2)$$

where  $B_{bap}$  is applied maximum number of buses per berth per hour (buses/h).

### 3.2.4. Application of the HCM2000 model for bus stops with two loading areas

Field observations from bus stops with two loading areas were compared to HCM2000 model results. The design of the loading area design determines how much extra capacity each additional loading area will provide;  $B_s = F_{ab} * B_{bb}$  where  $B_s$  is Bus Stop Capacity (TRB, 2000); and according to HCM2000:  $F_{ab} = 1.85$  for double loading area.

The field observations in Stockholm indicated that 1.85 is too high; therefore, a new assessment of the  $F_{ab}$  was performed. A detailed analysis was made to calculate the number of serviced buses in the first loading area at the bus stop to be able to calculate the value of the  $F_{ab}$ .

### 3.2.5. Estimation of $F_{ab}$

Field estimation of  $F_{ab}$  (calls  $F_{ap}$ ) for a double loading area as shown in Table 2 below was based on observed number of serviced buses in both loading areas using the same three methods as presented in Section 3.2.2.

Table 2. Calculation of the factor  $F_{ap}$  for double loading area by estimating the number of buses serviced at the first loading area.

Method	Proportion of buses in queue %	$Z_a$	$t_d$ (sec)	$C_v$	$t_c$ (sec)	Buses/h at first L	Buses/h at both Ls	$F_{ap}$	Average $F_{ap}$
<i>Östra Station; before &amp; after noon</i>									
Active time periods	>50	0	35.95	0.55	6.79	82	105	1.47	
Saturated condition	25	0.68	36.56	0.4	6.68	37	64	1.73	
Rush hours	6.4	1.5	35.95	0.55	6.79	22	31	1.39	
<i>Skanstull; before &amp; after noon</i>									
Active time periods	>50	0	48.77	0.51	9.16	68	79	1.34	1.4
Saturated condition	25	0.68	58.22	0.49	8.91	30	51	1.71	1.72
Rush hours	8.7	1.5	48.77	0.51	9.16	26	36	1.41	1.4

The results show values of  $F_{ap}$  which all are lower than HCM's  $F_{ab}$  1.85. The value of the saturated condition by 25% buses in the queue has a mean factor of 1.72, which was considered to be reasonable and rounded to  $F_{ap} = 1.7$ . Thereby the applied capacity of a dual stop position  $B_{sap}$  becomes:

$$B_{sap} = F_{ap} * B_{bap} = 1.7 * \frac{(0.4 + \frac{t_d}{1000}) * 3600}{t_c + t_d + Z_a * C_v * t_d} \quad (3)$$

where  $B_{sap}$  is Applied Bus Stop Capacity.

### 3.3. Tables for bus stop capacity

#### 3.3.1. Tables for bus stop capacity at one loading area

The loading areas along the bus line are divided in two main groups, on-line stop and off-line stops due to the different clearance time for these two cases. For this study loading areas have been classified into on-line and off-line types while the angle loading area type is dealt with in a separate table in Section 3.3.2.

- Curbside – loading area (on-line); means that buses stop along the curb and do not need to make a turning maneuver to exit
- Bus berth – loading area (off-line); means that buses need to leave the carriageway and turn in to the bay.

Passing vehicles in Sweden normally give way to departing buses at speeds less than 50 km/hour which gives low clearance times as stated in Table 3 below.

Table 3. Bus stop capacity at the on-line and off-line bus stops with variable dwell time and variable risk of queue.

Conditions	On-line bus stop $t_c=5$ sec $C_v=0.6$					Off-line bus stop $t_c=10$ sec $C_v=0.6$				
Dwell time $t_d$ sec	Number of buses/hour at queue risk					Number of buses/hour at queue risk				
	25%	10%	5%	2.50%	1%	25%	10%	5%	2.50%	1%
20	46	37	34	31	29	40	33	30	28	26
30	33	27	24	22	20	30	25	22	21	19
40	26	21	19	17	16	24	20	18	16	15
50	22	17	16	14	13	20	16	15	14	12
60	19	15	13	12	11	18	14	13	12	11
90	13	11	10	9	8	12	10	9	9	8
120	11	9	8	7	6	10	8	8	7	6
180	8	6	6	5	5	8	6	6	5	5

The table shows that the effect of the difference in exit time between on-line bus stop and off-line bus stop decreases as the dwell time at the bus stop increases and the queue risk reduces.

#### 3.3.2. Table for bus stop capacity at angle berth

The loading area design for angle stops differ from roadside bus stop types since the exit time is longer and queue risk must be minimized to avoid major disruption to bus flows. According to the calculation method above, the bus stop capacity for docking loading areas is based on a higher values for “coefficient of variation of dwell time at the bus stop,” ie,  $C_v = 0.6$  alternative 0.8 as below.

The table shows a reduction of number of departing buses with increased dwell time variation.

Table 4. Maximum number of buses/hour at angle berth with various accepted queue risk at  $C_v = 0.6$  alternative 0.8.

Conditions	Angle bus stop $t_c=30$ sec $C_v=0.6$					Angle bus stop $t_c=30$ sec $C_v=0.8$				
Dwell time $t_d$ sec	Number of buses/hour at queue risk					Number of buses/hour at queue risk				
	25%	10%	5%	2.50%	1%	25%	10%	5%	2.50%	1%
30	21	19	17	16	15	20	17	16	14	13
60	14	12	11	10	10	14	11	10	9	8
90	11	9	8	8	7	10	8	7	7	6
120	9	8	7	6	6	9	7	6	6	5
180	7	6	5	5	5	7	5	5	4	4

### 3.4. Validation of the applied equation (2)

Field measurements from Jakobsberg bus terminal could not be analyzed in the same way as for roadside bus stops since it is not possible to record any queue in the Angle berths. The analysis was therefore based on observations of short gap times between the exit and arrival of buses as indicator for a queue situation.

At the bus terminal in Jakobsberg bus drivers use different ways of waiting for an available bus stop position. Some bus drivers slow down, others wait at the location for passengers alighting. , Some drive around out of and in the terminal, which takes about two minutes, see Section 4 regarding analysis of bus terminal capacity below

Data collected at this bus terminal were processed using a threshold of 15 seconds for short gap times to capture the number of cases where the bus stop was unoccupied during time less than 15 seconds, 30 seconds and so on. Table 5 shows that during 52 minutes observation the bus stop was empty 3 times with shorter than 30 seconds and 2 times with shorter than 15 seconds.

Table 5. Example of indicators of queue situation at Angle berths H at Jakobsberg, with 15 sec marginal of unoccupied times.

Marginal time < x sec	Case nr	Bus nr	Departure time hh.mm.ss	Arrival time hh.mm.ss	Unoccupied time Sec
<15	1	2	06:57:08		
		3		06:57:17	9
	2	22	07:48:34		
		23		07:48:45	11
<30	3	18	07:36:04		
		20		07:36:28	24

The cases when the bus stop was unoccupied during less than 15 seconds were proven to be a good indicator of a queue situation. This applies to the cases when bus drivers wait for clearing of bus stop without driving around the terminal. The calculated  $Z_a$  from the HCM model gives an indication of the proportion of buses in the queue. Revising the equation without the term  $(g/C)$  results with  $Z_a$ :

$$Z_a = \frac{\left(\frac{3600}{B_{pb}}\right) - t_c - t_d}{C_v t_d} \quad (4)$$

While the applied equation results with  $Z_{ap}$ :

$$Z_{ap} = \frac{\left(\frac{\left(0.4 + \frac{t_d}{1000}\right) * 3600}{B_{bap}}\right) - t_c - t_d}{C_v t_d} \quad (5)$$

Comparisons between the results from these equations are presented in table 6 below:

Table 6. Comparison of HCM2000 with applied model for calculation of the risk of the queue.

H	Queue condition in 6 cases at the Angle berth H in Jakobsberg's bus terminal according to HCM2000 and to applied model					
Number	buses/h	$T_d$	$t_c$	$C_v$	$Z_a$	$Z_{ap}$
1	10	102.25	33.74	1.03	2.13	0.76
2	9	115.20	34.18	0.93	2.35	0.85
3	8	99.45	33.64	1.03	3.10	1.34
4	7	120.45	32.65	0.87	3.45	1.49
5	6	131.94	33.33	0.83	3.96	1.77
6	5	187.62	34.94	0.74	3.68	1.51



Table 6 shows that using the HCM2000 model gave  $Z_a$  value 2.13 or higher, which mean very low queue risk. However table 4 shows that there were high percentages of buses with short time gap between departing and arriving times. These field observations better fit to results from  $Z_{ap}$ , which confirms the need to adjust HCM2000 model with the estimated correction factor  $CF = 0.4 + t_d / 1000$ .

#### 4. Bus terminal capacity

A **bus terminal** is here defined as a facility for alighting and boarding of passengers from several bus lines for interconnection or transfer to other modes of transport (e.g. subway, bicycling, walking). **Bus terminal capacity** can be defined as the total number of buses that can be served by the terminal per time unit (e.g. hour) at a given frequency ratio for each bus line. Since each terminal has a unique design, the following general factors that may affect the capacity of terminal need to be considered;

- Traffic operation planning (bus route cycle, location of buses, frequency and driver exchange)
- Time scheduling (percentage of lines that connect to train arrivals/departures.)
- Terminal type (along the street, island-terminals, laminal berths, sawtooth berths)
- Terminal design (turning possibilities, bus movements needed to avoid conflicts between buses and with passengers, bus exit capacity)
- The purpose and function of the bus stop (alighting, time control, boarding or combination of these functions i.e. alighting, control, boarding)
- Type of bus line (turning, passing through, occurrence of replacement services)
- Interference due to traffic congestion and other traffic (authorized and unauthorized) can reduce bus stop capacity in the terminal.
- Other factors, e.g. vehicle type or driver behavior.

To estimate bus terminal capacity two methods can be used:

##### *Method A: Empirical analysis*

###### Case 1: Independent bus movements

If the terminal design permits all buses to arrive and depart from their assigned bus stop without any interference with buses to and from other bus stops in the terminal, the following simplified deterministic procedure can be applied:

- Calculate the capacity of each bus stop as described in Section 3. This calculation includes the effect of clearance time needed for a bus to depart from the bus stop including pedestrians crossing in front of the bus. The calculation is usually made for the design time (rush hour), but can also be needed for other time periods depending on connections with other public transport modes. The results (number of buses per hour) should be adjusted to fit the planned bus timetable.
- Calculate total terminal capacity as the sum of all bus stop capacities using the methods in Section 3 above.
- Check connecting road system entrance and exit capacity for buses arriving to and departing from the terminal, and revise the total capacity obtained in the previous step accordingly.

The total terminal capacity can then be determined as:

$$B_t = \sum B_s \quad (6)$$

where:  $B_t$  is Bus terminal capacity;  $B_s$  is Bus stop capacity.

###### Case 2: Dependent bus movements

At higher traffic load the terminal capacity can be reduced by factors such as queuing buses, blocking entrance or exit from bus stops for other bus lines, passengers moving across the terminal, limited terminal entry or exit capacity etc. The total terminal capacity can then be determined as:

$$B_t = \sum B_s * [1 - \text{Reduction rate due to other factors (traffic loads + passengers' movement + ... + limited exit capacity)}] \quad (7)$$

*Method B: Simulation of bus terminal operation*

Simulation is normally required to estimate terminal capacity and delays for dependent bus movements, since deterministic methods can only be applied for very simple cases. A model for micro simulation of bus terminal operation need to include the following main features and types of input data:

- Bus terminal design including type, location and loading bays for all bus stops
- Location, direction and interconnections for all bus paths to and from each bus stop
- Pedestrian walkways, crossings and islands/platforms
- Arrival distribution to the terminal entrance for all bus lines
- Operating strategy for allocation of bus stop for arriving buses
- Time tables for planned bus stop departure for all bus lines
- Bus length, acceleration and speed for travel inside the terminal
- Bus capacity for boarding and alighting (passenger per second)
- Passenger arrival distribution at each bus stop

Time based simulations at given demand levels can then obtain the following types of results:

- Travel time and delay for each bus from terminal entry to assigned bus stop and then to terminal exit.
- Location, length and duration of bus queues inside the terminal
- Bus flows at terminal entry and exit per time unit
- Terminal capacity (highest bus flow before breakdown of terminal operation)

## 5. Recommendations for future work

The study recorded in this paper is a first step, several studies are needed. Suggestions for future work are:

- Graphs with different values for  $Z_a$ ,  $C_v$  etc. are needed as supplement to the capacity tables;
- Design guidelines regarding bus stop distance to the pedestrian crosswalks and intersections with regard to the capacity of the bus stop;
- Further development of models for bus terminal capacity which take into consideration influencing factors and further discussions concerning:
  - The safety margin between the reversing area and passing area of angle terminals,
  - Effect of dedicated alighting area on the terminal capacity,
  - The ratio of bus parking spaces to the number of loading areas,
  - Socio-economic analysis of congestion and longer detours.

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